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Sustainable food systems: do agricultural economists have a role?

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Abstract

Are agricultural economists losing their relevance and significance in research on sustainable food systems? Could the world thrive without the contribution of agricultural economists? How could agricultural economists have more impact in addressing the grand challenges of our time? In this paper we address these questions by reflecting on the field of agricultural economics and re-examining the role and impact of agricultural economists. We argue that agricultural economists could raise their impact through better collaboration with other disciplines, stakeholder engagement and the adoption of a more systematic approach to the grand challenges, the innovation pathways and their disrupting developments in the data economy. We outline key topics in the economics of food systems on which agricultural economists could make major contributions and key areas in which methodological innovations are needed.

Keywords: Food systems, agricultural economics, data economy

JEL classification: Q00

1. Introduction

Thousands of research articles have been published on sustainable food systems in the past 5 years. But is it clear where agricultural economists stand? The lack of pronounced views by agricultural economists on a subject so closely knit with their field suggests a problem that needs urgent attention. Are agricultural economists losing their relevance and significance in research on sustainable food systems? Could the world thrive without the contribution of agricultural economists? How could agricultural economists have more impact in addressing the grand challenges of our time?

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This paper aims to offer our insights into how agricultural economists could have more impact through better collaboration with other disciplines, stakeholder engagement and the adoption of a systemic approach to the analysis of food systems. We argue that agricultural economists could raise their impact by focusing on the major global challenges from a food systems perspective, taking a more integrative approach to supporting the transformations needed. This includes the use of more multi- and transdisciplinary approaches. To support our argument we start by imaging a world without agricultural economists to appreciate where they stand and proceed to address the grand challenges and opportunities ahead.

Disciplines in science are not only characterised by subject matters and typical approaches used, but also characterised by social organisations with own professional standards, journals and education programmes which provide their identity (Janssen and Goldsworthy, 1996). Agricultural economics as a discipline has developed over time, studying new problems with new methodologies (Runge, 2006). As we argue in the next section, should this development continue without critical rethinking on their main focus and strength, agricultural economists as a collective may lose their significance. Some of the standard economic methods (like cost price calculations or consumer research) will then be taken up by other agricultural scientists and we could enter a world without specialised agricultural economists.

The Sustainable Development Goals (SDGs) illustrate that we have important global challenges. Fortunately there are also innovation pathways with new technologies and social practices (Section 3). These ask for a food systems approach that entails transformation of existing systems and redesign of the system. Inevitably there will be competing claims and trade-offs. These need to be made explicit and carefully evaluated following the framework of responsible innovation. Agricultural economists could take up this societal need and collaborate more with other scientific disciplines on such a complex task. That calls for multi- and transdisciplinary research and an agricultural knowledge and innovation system that supports this (Section 4). Based on the innovation pathways that are often linked to information and communication technologies, we suggest that big data economics is going to play a more prominent role in economic research. Using the new institutional economics framework, we argue that this should not only lead to agricultural economists using big data sets to analyse the performance of food systems, but also that they look to the governance and institutional aspects of the data economy and the design of improved food systems. The paper ends with the conclusion that agricultural economists should transform into such a kind of food system economists in order to stay relevant.

2. A world without agricultural economists

A key theme in economic analysis is the evaluation of alternatives and trade-offs (Buchanan, 1964). This often involves the use of counterfactuals, i.e. ‘what ifs’. To investigate the current and future role of agricultural economists,

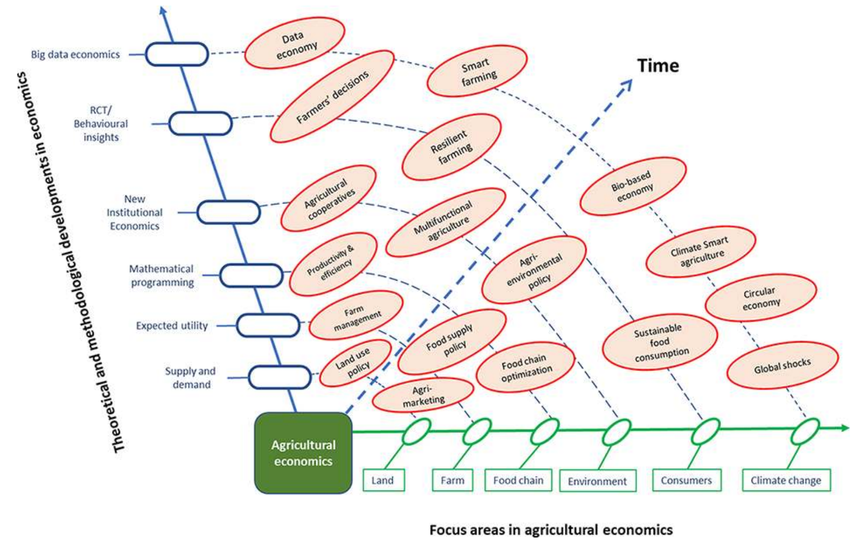

Fig. 1. The expanding field of agricultural economics.

it might be worthwhile to use the thinking of economic analysis and define the counterfactual as a world without agricultural economists. What is it that agricultural economists contribute and what would we lose without it?

Agricultural economics was among the first and largest applied economics discipline that started to use economic principles to problems with farm management and agricultural policies (Runge, 2006). As a poster child of applied economics, agricultural economics has been evolving and expanding both in the scope of the problems and in the variety of economic approaches (Zilberman, 2019). A brief survey of major journals in agricultural economics (e.g. European Review of Agricultural Economics, American Review of Agricultural Economics and Journal of Agricultural Economics) reveals an ever-expanding field of study carried out by agricultural economists. Historically, the interests of agricultural economists have developed over two axes: the set of theoretical and methodological approaches and the series of evolving focus areas or phenomena being studied. This is characterised by the rising number of 'hotspots' combining new focus areas and methodological developments as shown in Figure 1.

On both axes agricultural economists have been fanning out. Contemporary economics is diverse as there are many schools and a variety of approaches (Dow, 2007). These range from normative to positive economics and from micro and macro to institutional economics. Over the past decades, there have been profound changes in the structure of economics as evidenced by the development of the Journal of Economic Literature codes (Cherrier, 2017). Agricultural economists not only differ in their main ideas and analytical devices, but also in their levels of analysis and practical applications to agricultural policies. The phenomena with which agricultural economists are concerned are production, consumption, distribution and exchange of goods and services produced from or of land and other natural resources—particularly, but not necessarily via markets.

With the expansion of topics studied, the beneficiaries of agricultural economists have been broadened from farmers and land managers to public policymakers, financial institutions and food chain companies. Non-governmental organisations are nowadays also in the clientele. Policymakers look to economics to guide policy, and it seems inevitable that even the 'esoteric' issues in theoretical economics may have serious bearings on people's material interests. The extent to which economics bears on and may be influenced by normative concerns raises methodological questions about the relationships between a *positive* science concerning 'facts' and a *normative* inquiry into values and what ought to be (Weston, 1994).

While this short overview suggests a continuous development and progress in diverging and specialised topics, it also underlines a standstill in connecting, consolidating and reinvigorating the power of economic thinking across different 'hotspots' that is creating an existential problem for the discipline. The discipline has spawned an archipelago of sub-disciplines. The complex challenges faced by the food systems cannot be addressed by these sub-disciplines individually and, seemingly disconnected, they lack a collective identity.

Methodologies of the discipline have become standardised and commoditised products. One does not need a PhD in agricultural economics to do a cost price calculation, a simple consumer survey, a linear programming or a simple cost–benefit analysis. It can be tempting for natural scientists with some basic training in a social science course to carry out such a type of research themselves instead of going into the hassle of multidisciplinary project management. In the same way it can be tempting for policymakers and other scientists that support them to restrict their impact analysis to first-order effects of a policy intervention. As policymakers tend anyway to divide a complex problem at the time of a crisis into more manageable smaller issues, such a partial approach is not optimal.

Although standardised methods and techniques from agricultural economics may survive, a world without agricultural economists is a world in which new, more complex problems are not covered and new methodologies not developed that are tailored to the problem in this domain. That would result in partial solutions based on standard methods of which the underlying assumptions and indirect effects are not well-understood. While it is certainly possible to imagine a world without agricultural economists, it is highly uncertain that policy choices made are among the best ones for which costs and benefits are carefully weighed against each other (integrated evaluation), including institutional costs and changing value frames.

With this counterfactual in mind, let us in the next section explore how the focus area of agricultural economics can be revitalised and what are the new trade-offs and valuation issues that should be considered.

3. Grand challenges call for a food systems approach

3.1. Grand challenges and innovation pathways

The world faces several grand challenges related to food production and consumption. Most of the SDGs relate to food and farming. These challenges are extensively documented (Arora, 2018; De Schutter, 2017; Fresco and Poppe, 2016; HLPE, 2017; Moreddu, 2013) and can be summarised as follows:

- Safeguarding food and nutrition security for a world population that is expected to approach 10 billion by 2050.
- Resolving climate change (adaptation and mitigation), pollution and biodiversity loss.
- Achieving healthy diets across the globe.
- Reaching equality in wealth and welfare by providing livelihoods for farmers and others across the food chain while bringing well-being for the rural communities.

These grand challenges are also the driving force for innovations that can potentially transform the status quo into a more sustainable, healthy and inclusive food system. Promising new developments include genetics (with techniques like clustered regularly interspaced short palindromic repeats (CRISPR)-CRISPR-associated (Cas)), precision farming, circular agriculture, the energy-, bio-based- and protein transition, and personalised nutrition and health. Digitalisation is a key enabler for many promising developments as it brings automatisation, mass interactive communication, modern sensing and the ability to process and analyse big data sets. In addition to these novelties, innovations originate from society due to changes in consumer demands or new institutional arrangements and social practices. Examples can be found in and around cities where farmers offer services such as leisure, care and nature management as well as food production. Also, citizens are becoming increasingly involved in co-creation processes needed to change our current food system (Fresco and Poppe, 2016).

Although there are numerous actors that experiment with sustainable alternatives for the status quo, the grand food challenges are here to stay for some time. The ability to transform the food system is hampered, not only because innovations are still under development, but also due to the change-resistant dynamics of the status quo. Examples of dynamics that hinder change are vested economic interests, established routines, rules and dependencies, and existing technical and digital infrastructures. The grand challenges are interconnected and form a 'wicked problem' (as described in Rittel and Webber, 1973) with incomplete or even contradictory knowledge and many people and opinions involved. These aspects need to be taken into account when working on innovation pathways.

3.2. Food systems

The grand food-related challenges cut across policy domains, scientific disciplines, sectors, institutions and borders. Science and policy aiming at

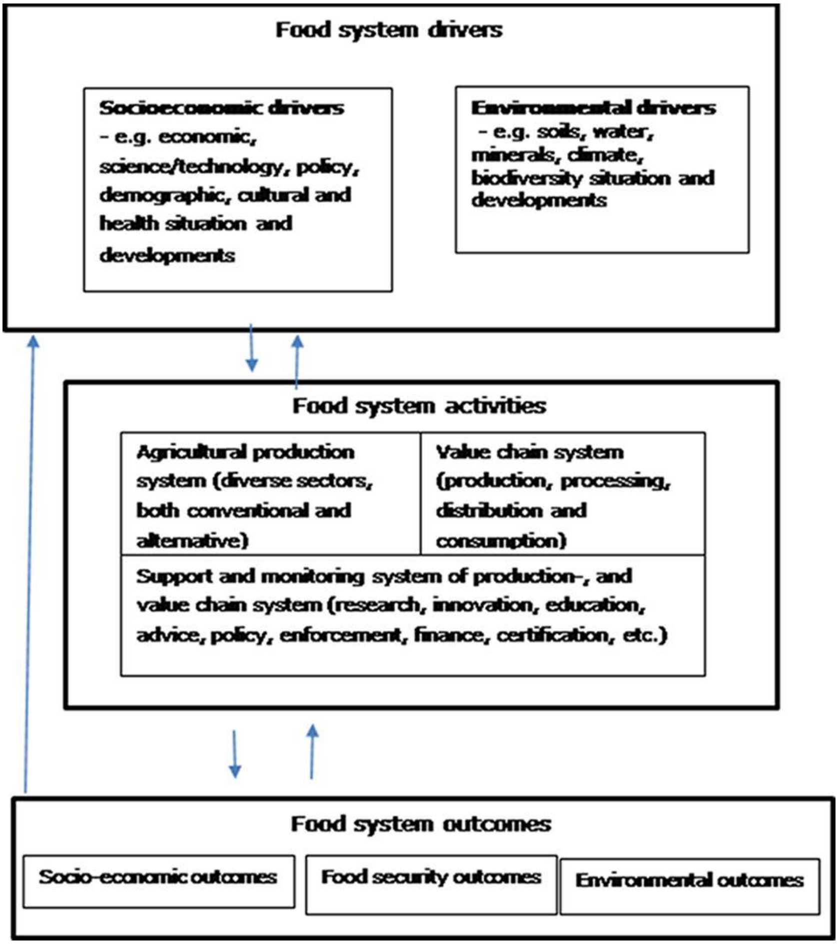

Fig. 2. The food system (combined and adapted from (Gaitán-Cremaschi *et al.*, 2018), (Van Berkum, Dengerink and Ruben 2018) and (Ericksen 2008)).

contributing to solving these grand challenges should therefore go beyond focusing on the farm and/or value chain level but also take into account the wider drivers, activities and outcomes in the food system (European Commission, 2016, 2019; Fresco and Poppe, 2016; Halberg and Westhoek, 2019; Sonnino, Tegoni and De Cunto, 2019). The High Level Panel of Experts (HLPE) of the Committee on World Food Security defines food systems as 'all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes' (HLPE, 2017). Figure 2 provides an abstract overview of this definition and illustrates that both socio-economic and environmental factors influence the food system activities. Food system activities include a broad range of conventional and alternative farming/fishery/horticultural activities and the activities in related value chains, research, education, policy and advice. The outcomes of these activities provide food security as well as socio-economic and environmental impacts (Ericksen, 2008; Gaitán-Cremaschi *et al.*, 2019). It should be noted that Figure 2 provides a rather static view of the food systems and does not include the change processes in the food system and the actors involved. The value of Figure 2 is that it illustrates the intricate web of interlinked activities and feedback in a schematic and not too complicated way.

The food system perspective raises awareness about:

- The complex web of interaction among actors, hardware, data, food, the environment, institutions, etc. with feedback loops, accumulations, trade-offs and synergies, which may result in (unforeseen) outcomes on the short or long term, such as climate change and public health issues.
- The notion that the root of the problem or promising solutions may be at very different places in the food system than the place where the problem is most visible.
- The fact that many actors across different disciples, sectors, institutions and cultures influence the activities and outcomes of the food system (Hoes *et al.*, 2019).

Food systems also clarify that the transformative capacity for changing the way societies produce and consume food is low. The unwanted environmental and health outcomes, especially at the level of farmers and consumers, are a wicked problem and not solved easily by for example a few governmental interventions that correct a market failure or some new products launched by start-ups that see a problem as a business opportunity—although these activities do play a role in changing the food system in the long term. A system transformation requires collective problem analysis and action across various fields, including agriculture, environment, energy, health, education, infrastructure and planning. A major challenge in deciding upon which interventions to take is the uncertainties with regard to outcomes due to the non-linear processes, feedback loops and trade-offs that occur in food systems. Impacts of interventions go beyond the place, and time, where the intervention occurs. Economists can assist society in making more transparent the trade-offs that can be expected for the different intervention strategies. And although impacts cannot be fully predicted, uncertainties and risks can be reduced through so-called food system analysis (Hoes *et al.*, 2019b; Posthumus *et al.*, 2019; Van Berkum, Dengerink and Ruben, 2018). Boxes 1–3 provide examples for three major food systems at different geographical levels on challenges, innovation pathways and trade-offs.

3.3. Trade-offs in the food system

Trade-offs make it clear that not everything is possible or comes for free. In economics, trade-offs are generally about making explicit the cost and benefits of actions. Cost, not only in a monetary sense but also in lost time, pleasure,

Box 1. Fruit and vegetable food systems in metropoles

Food system: Supplying the metropoles with fresh fruit and vegetables is a challenge. Their relative price versus processed products increased, as improving labour productivity and good logistics are difficult. Cities traditionally rely on small farmers at the edge of the city, offering their produce on wet markets. Upcoming supermarkets find it hard to guarantee the food safety and availability of the products.

Grand challenges and innovation pathways: Big metropoles of the world are inhabited by many food and nutrition insecure households as well as with a growing middle class that shop in supermarkets. Lifestyle-related diseases are an important health cost. Achieving healthy diets and reducing inequality by providing livelihoods for city dwellers and for small farmers is a challenge. Several innovation pathways exist: supporting smallholders to adopt food safety and quality standards, organising them with cooperatives, capital-intensive large-scale production in glasshouses and vertical farming within cities that need management expertise, micro-gardens, etc.

Trade-offs: Every innovation pathway has its own pros and cons. Healthy diets are not per definition sustainable. Intervention can take place with different policy instruments and at different stages in the food chain. Land can be used for vegetable growing or expanding the metropole. Regulating food safety can increase the cost of food.

status, comfort, relationships, etc., specifically the concept of opportunity cost of one potential choice is well-known (Buchanan, 1991).

Analysis of trade-offs of interventions that take into account a food systems perspective are about forecasting possible impacts beyond the economic, food security or environmental domain and beyond the sphere of the farmer, consumer or value chain. Considering multiple criteria makes trade-offs explicit, this leads to more informed and better decisions. In addition to make trade-offs explicit, food system analysis can also be used to identify where limited efforts can have a large positive contribution to food and nutrition security (Dengerink *et al.*, 2019). Economists can assist policy by making explicit the following anticipated consequences for different interventions to redesign the food system:

- Which actors or actor groups benefit and suffer from policy interventions?
- Which SDGs are reached (at the costs of other goals) and which not?
- The distributional effect among for example sectors, regional scales and links in the value chain.

Having discussed how the focus area of agricultural economists can move from individual actors or topics to food systems to solve the grand challenges, it is also logical to see what this implies for the other axis in Figure 1: the methodological approach of the discipline. In particular, have we made sufficient use of the economic toolbox? Are new tools needed? Given the wickedness of the problems, an important aspect of

Box 2. Food systems based on arable farming of commodities for global markets

Food system: A large part of agricultural land is used for growing commodities like cereals, sugar and potatoes that farmers market as commodities to the food processing industry. The markets are international, with future markets and a financing system that supports the value chain. In some cases the land is rented from institutional investors. Besides processed food, mostly sold via retail, a large part of the products is upgraded by the feed and livestock industry into eggs, (pig and poultry) meat and even dairy products.

Grand challenges and innovation pathways: Arable farms are hardly circular. Phosphate and nitrate lead to water pollution or end up in the purification plants of the cities. Heavy machinery leads to compaction of soils. Large fields with monocropping negatively effects biodiversity. The meat industry is regionally concentrated with environmental and animal welfare problems. There are innovation pathways in strip farming and robotics with a 'smart farming' approach, no-tilling practices, improved breeding (CRISPR-Cas), better housing for livestock, reducing meat consumption and introduction of plant-based meat-like products.

Trade-offs: There are trade-offs between ethical values (animal welfare and use of genetically modified organism) and financial values. Should we close loops by locating the livestock industry where the cereals are grown? Should livestock be fully based on recycling of waste from the food industry? How to motivate farmers in environmentally friendly practices: knowledge, subsidies and regulation? Is biodiversity best helped with sharing or sparing land? Do smart farming technologies move decision-making from the farm to the tech companies? Should the government have access to that data to subsidise or regulate the farmers? Should the input and food processing industry, being powerful contractors, be forced into sustainable contracting? How to nudge the consumer away from too much meat?

that approach is a multidisciplinary approach to understand and transform food systems (Section 4). Other aspects are the methods and techniques (Section 5).

4. Economics in a food systems approach

4.1. Economics in a multidisciplinary approach

The complexity of redesigning the food system asks for a multidisciplinary[1] approach that requires concerted efforts between disciplines and new institutions that facilitate this collaboration. Economists are well-placed to play a role in this. When natural scientists work with social scientists, it is mostly with economists (Barthel and Seidl, 2017; Mooney *et al.*, 2013). To better understand the implication of multidisciplinary approaches for

1 We use the term multidisciplinary in a broad sense, without going into detail on all the prefixes like mono-, multi-, inter- and transdisciplinary.

Box 3. Dutch dairy food system

Food system: The Netherlands is a fertile region with a temperate climate with wet grasslands that are better suited to dairy than arable farming. It has a dense infrastructure and Europe's largest port, Rotterdam, which imports products such as soya feed and exports dairy products such as baby milk powder. Sixteen thousand and five hundred dairy farms keep 1.6 million cows. Farmers are paid in the Common Agricultural Policy (CAP) for schemes that support meadow birds, and dairy processors have with the support of an non-governmental organisation (NGO) and auditors introduced labels for 'planet proof' milk.

Grand challenges and innovation pathways: The industrialised system has negative externalities in emissions of ammonia, phosphate and greenhouse gasses. Dairy farms keep the landscape open and grazing cows in the pastures are an iconic view of the polders. Improved feed and breeding, new housing systems including smart farm practices, a more grass-fed farming system with less cows per hectare (and in total), a focus on higher added value cheese making or special products for the young and elderly and a shift to plant-based dairy products are some of the innovation pathways for the system.

Trade-offs: Many. For some environmental issues cows should be kept inside, for others outside. Inside also means a trade-off with cultural values. Should farmers or dairy processors be subsidised or regulated on environmental issues? Is there an effect on the level playing field for this export sector, and would a reallocation of Dutch production to elsewhere be good or bad for the world? Should the input and processing industry further internationalise and how to organise that as cooperative? Would emission trading help and could farmers on peat soils (that release greenhouse gasses) benefit from it?

economists, this section first reflects on the sociology of science explaining agricultural economics as a quasi-discipline in relation to other scientific disciplines (Section 4.2). This is a basis to describe the challenges of multidisciplinary collaboration between economics and different scientific disciplines in reaching both academic and societal impacts (Section 4.3). As the organisation of research and innovation (R&I) activities influences the possibilities for a multidisciplinary approach, we practically explain more in-depth the institutionalised agricultural knowledge and innovation systems (AKIS) approach, as part of our food system (Section 4.4). Besides a multidisciplinary approach, economists could raise their impact also by sharpening their toolbox to address the challenges and trade-offs in our food system, mentioned in Sections 2 and 3.

4.2. Quasi-disciplines and frontier research

We refer to food system–related sciences, in which agricultural research plays one of the central roles, as quasi-disciplines because the core of this research is not defined by the internal state of its fields (as in e.g. mathematics) but by external influences outside these disciplines (Ben-David, 1971). Business administration, marketing and medical and health science, which are also related to food systems, are other examples. Quasi-disciplines are formed

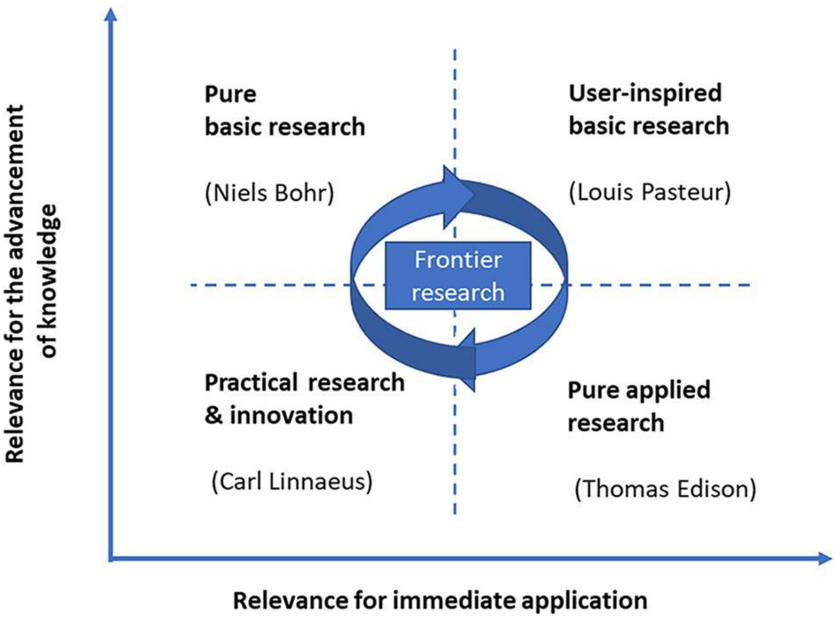

Fig. 3. Types of research, classified to relevance for advancement of knowledge and of immediate application, with some examples. Adapted from Stokes, (2011).

when a certain type of problem occurs frequently (Janssen and Goldsworthy, 1996). From this perspective, agricultural economics is essentially a quasi-discipline.

The difference between disciplines and quasi-disciplines can be compared to the categorisation of basic research (curiosity-driven) and applied research (problem-driven), see Figure 3. While basic economic research, as e.g. carried out by Pigou on externalities (Pigou, 2017) or Coase on transaction and social costs (Coase, 1960), is carried out in economic faculties such as Chicago and Cambridge, most agricultural economists are rather driven by their relevance for application to global challenges, regardless of whether they work in e.g. faculties, applied research institutes or think tanks. From this categorisation, food systems research is necessarily a frontier research at the cross-roads of pluralistic approaches and multiplicity of topical issues (Jahn *et al.*, 2009).

4.3. Barriers and challenges in multidisciplinary collaboration

Given the differentiation in scientific disciples, quasi-disciplines and types of research as pointed out in Figure 3, there is an increased demand for collaboration in multidisciplinary approaches to address the complexity and interdependence of the different challenges and trade-offs in our food systems (Fry, 2001; Janssen and Goldsworthy, 1996; Vandermeulen and Van Huylenbroeck, 2008). For example in analysing European Union (EU)-funded projects like SEAMLESS, SENSOR and LUPIS that integrated biophysical, economic and social systems through research consortia, from a variety of disciplinary backgrounds, Kragt *et al.*, (2016) note that the 'interest in models that integrate biophysical and economic components of agri-environmental systems has increased, largely in recognition of the multiple services provided by agri-environmental systems and reflecting the complexity of "multi-functional" agriculture'. However, a review of interdisciplinary projects that were carried out under the EU Fifth Framework Directive concluded that 'disappointingly few projects are clearly interdisciplinary, particularly in terms of crossing the boundary between natural and social sciences' (Bruce *et al.*, 2004). The demand for multidisciplinary work does not in the least rule out the strength and capacity of monodisciplinary research tackling complex problems such as e.g. quantum mechanics, relativity theory and statistical mechanics in physics (Lockeretz, 1991). However, multidisciplinary collaboration does face challenges. The following four barriers have been identified to hinder multidisciplinary collaboration in system approaches (Dobbs, 1987; Mooney *et al.*, 2013; Young, 1995).

4.3.1. Differences in methodology and vocabulary

Working across disciplines does not mean that one can assume that team members know each other's discipline, which makes team communication, common language, defining (quantitative and qualitative) methods, terminology, etc. challenging (Fry, 2001; Kragt *et al.*, 2016; Mooney *et al.*, 2013; Stock and Burton, 2011). It already commences with the formation of a team or project, e.g. when social scientists are invited (last minute) by natural scientists to satisfy societal requirements by research funders such as basic economic analyses (Barthel and Seidl, 2017). This does not help reducing disciplinary chauvinism. Moreover, related to population growth and food supply, emphasis on limitations and pessimism of economics as a 'dismal science' is deeply rooted: 'There is no essential contradiction between the underlying philosophy of economics, related to resource limitations and trade-offs, and that of the natural sciences, related to technical solutions for resource limitation problems' (Dobbs, 1987). Yet, the tension becomes clear when agricultural economics and natural science disciplines are brought together in the context of technology adoption. Politicians, farm organisations and managing authorities tend to prefer the more positive point of views by natural scientists and engineers over the recommendations by economists who stress second-order or rebound effects (Dobbs, 1987). Hope keeps the world spinning. There is also a similar tension between ecologists and economists. Ecologists often prefer regulation over market-based solutions. The economy is, not incorrectly, seen as the root of ecological problems, which leads to tendency to reject market-based solutions such as tradable emission rights (Kragt *et al.*, 2016). It becomes clear that not only researchers should better find their common ground in multidisciplinary research, the end-user actors who decide or use the research outcomes in daily practice (SCAR AKIS, 2019) need to be involved equally to be able to co-create adequate transdisciplinary solutions.

4.3.2. Resistance from the institutional environment

The second challenge that collaboration between disciplines faces is the institutional environment and in particular due to the role of (top) management. Success or failure largely depends on both the organisation and the financing of research, while striving for an optimal balance between monodisciplinary and multidisciplinary research. This is particularly challenging for quasi-disciplines such as agricultural economics, since these economists have to stay up-to-date in basic economic theories and scientific methods for rigour and credibility on one hand, while applying these in their work at the same time (Padberg, 1987). While granting agencies and academic administrators strongly support multidisciplinary research, the promotion and tenure criteria at the organisational level still rely heavily on disciplinary academic impact. This essential gap needs major adjustments, to not only evaluate the scientific outcome but to justify the societal impact of multidisciplinary research also (Mooney *et al.*, 2013; Stark, 1995).

4.3.3. Disciplinary chauvinism

Disciplinary chauvinism implies a preference in the economics discipline for monodisciplinary research when multidisciplinary research is seen as negatively affecting publication records, professional images, career opportunities, etc. Each discipline or quasi-discipline has developed its own ways of working and reward systems to conserve this, such as the monodisciplinary scope of journals and top journals in particular. Journals which publish multidisciplinary research have on average lower impact factors and these papers are cited much less than their monodisciplinary siblings. For example, in the case of groundwater research, multidisciplinary papers typically appear in social scientific or multidisciplinary-oriented journals, rather than in journals on water resources (Barthel and Seidl, 2017). However, although observations on the difference in reward systems between disciplines are frequently tabled, researchers performing multidisciplinary research do not seem to be too hindered by it (Fry, 2001; Mooney *et al.*, 2013; Young, 1995). Both internal and external stimuli to motivate the continuing development of multidisciplinary research are increasing.

4.3.4. Perceived parasitism

Perceived parasitism suggests that either economists perceive their time or expertise as ‘stolen’ or other scientists perceive their data as ‘stolen’, due to a lack of credits for data collected in their (e.g. physical) domain (Dobbs, 1987). Because economists often perform their work and analyses at the end of multidisciplinary projects while using the obtained biological and physical data, this can invoke such feelings. Agricultural economists can see themselves as victims when e.g. the other scientists claimed more research time for their activities than planned and their time is cut given an unchanged deadline of a multidisciplinary project. The fact that some other scientists carry out standard economic analyses themselves adds up to the perceived parasitism.

These four challenges raise the question what can be done and in particular what administrators, research managers and researchers themselves can do to increase the feasibility of complex multidisciplinary research. We notice a shift from traditional forms of collaborating in projects in which two or more disciplines collaborate more or less separately towards opening these siloes by accepting networks of different, multiple actors co-creating and defining interdisciplinary language and communication. Multidisciplinary collaboration is rather about ‘generating social capital and cohesion, by effectively building teams and ensuring cultural understanding amongst all actors involved who have roles to play on the problem or project in question’ (Mumuni, Kaliannan and O’Reilly, 2016). Experienced facilitators such as innovation brokers or free actors play essential intermediary roles in building trust and finding the communality between these actors that is needed in order to be able to tackle the wicked problems such as those faced by our food systems, together (Jakobsen, Hels and McLaughlin, 2004; Kragt *et al.*, 2016; Wielinga and Geerling-Eiff, 2009). The complexity of a multidisciplinary project can be classified (see e.g. STRAP labelling, Chubin, Porter and Rossini, 1986). A multidisciplinary model based on systems theory in which different disciplines are combined should be developed by all actors involved (researchers, intermediaries and end users), to avoid a fallback into single disciplinary approaches which do not (adequately) address the overall problems of the system (Janssen and Goldsworthy, 1996).

The next section describes the AKIS as a systemic approach to handle the aforementioned obstacles and to optimise knowledge flows, bridging the gap between research and practice for innovation.

4.4. AKIS: institutionalising agricultural knowledge and innovation in food systems

To link the relevance of the advancement and (immediate) applications of knowledge flows to enhance innovation, a systemic approach of AKIS has been and is being implemented in societies worldwide. Like the food systems concept, AKIS has had a knock-on effect and evolved from an academic methodology (Klerkx, Van Mierlo and Leeuwis, 2012; Röling and Wagemakers, 1998) into a policy and practical approach e.g. by the EU and its member states with respect to the CAP, in combination with the R&I framework programme Horizon 2020 (Knierim *et al.*, 2015; Moreddu, 2013; Poppe *et al.*, 2018a). It is a useful concept to indicate and describe the overarching combination and organisation of interactions and knowledge flows between the different AKIS actors: agricultural entrepreneurs, knowledge workers (from extension, education, advisory services and research), the government and all other actors in the agri-food value chain (from input suppliers up to the consumers), banks, NGOs, media, etc. (EU SCAR, 2012, 2013, 2015).

The idea to improve this part of the food system by enhancing connections between science and practice and to boost knowledge exchange and innovation for the benefit of sustainable agriculture has gained significant support and importance (Läpple, Barham and Chavas, 2020). However, the emphasis on an integrated approach for knowledge and innovation within food systems, to address the challenges and trade-offs as described in Chapter 2, raises the question if AKIS systems are fit for purpose. First, the focus on traditional agriculture and forestry knowledge and innovation is strongly dominant. The usual suspects involved are the traditional agricultural faculties and research institutes, focusing e.g. either on crops or animal husbandry. Apart from the combination of agriculture and information and communication technology (ICT), cross-sectoral research with other disciplines related to e.g. water, energy and health is often still limited. Second, there is much attention for the role of advisors as intermediaries in AKIS as pivots in enhancing the match between knowledge and practice, while the role of research and education to take up a more intermediary, hybrid function in this process, is still underexposed. A third barrier refers to the risks of the multi-actor approach[2] within AKIS, to involve all actors in co-creating knowledge for optimal impact and co-ownership of solutions, stimulating knowledge transfer and exchange to speed up innovation (EU Scar, 2019). It is e.g. a time-consuming process to involve as many relevant actors as possible: it takes experienced know-how and expertise to come to a collective goal and mind-set and to define and manage all actors' roles along the process. Hence, multi-actor research can easily lead to different perspectives, expectations and loss of focus in research aims, like blindly trying to define an elephant together. At the same time there is however a call for more transdisciplinary research with a citizens' science approach, which means with public participation in gathering, interpreting or analysing data. Essentially it implies the production of knowledge and innovation by a collective. Examples can be found in local food systems and (farm) nature management.

To conclude, AKIS systems are an integral part of and form important stepping stones in many countries as building bricks for the development of food knowledge and innovation systems. But more work is needed on the highlighted issues in connecting different types of knowledge and linkages among knowledge, innovation and practical implementation in food systems.

5. Raising the impact of food systems economists

A food systems perspective shows us that we are facing wicked problems which cannot be resolved by sole forms of basic or applied research. Agricultural economists must act as frontier researchers who combine both types of research in different institutional settings, aiming at both scientific and practical impact while collaborating and cross-fertilising with other disciplines. To answer that question, we rephrase the findings of the last section in the terminology of the new institutional economics (NIE).

2 https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-food_en.pdf.

5.1. The economics of institutions

Institutions are the formal and informal rules that organise social, political and economic relations (North, 1990). For a long time the economics of institutions had been only marginally explored because of its elusiveness and complexity. The role of institutions and their impact on economic performance and social interactions were however made clear by the school of NIE (Williamson, 2000). NIE has won great accolades in addressing social or environmental problems related to governance and coordination, addressing well-known problems such as 'the tragedy of the commons', 'free-riders' and hold-up problems in collective or collaborative actions (see e.g. Ostrom, 1986, 2008).

The first five rows of Table 1 show the classical introduction to NIE with its four levels of social analysis and the issues studied based on Williamson (2000).

It could however be discussed whether the speed of change taking place in different levels of analysis as postulated by Williamson is still valid. It looks as if a considerable acceleration has taken place due to the developments in ICT. Changes are now happening at a much faster pace than two decades ago. The establishment of new legal or governance institutions that used to take years, if not decades, is now happening much quicker. Either we are not living in an era of change, but in a change of era—or change is speeding up. Whatever the case, this acceleration, accompanied by the explosive increase of data, has created considerable chaos and confusion in the social fabric locally and globally.

Following this framework we added to Table 1 issues in multidisciplinary research and the four barriers to multidisciplinary research discussed in Section 4.3 as they naturally correspond to the four levels of analysis in NIE. This suggests that researchers in multidisciplinary research who want to resolve discussions on perceived parasitism should look to higher levels of coordination for a solution. In the end it is, also to our own experience in Wageningen, the problems of language and methodology that have to be tackled for a successful cooperation between (quasi)disciplines.

The NIE also offers a useful framework for frontier food system economists to address systemic problems/challenges while it implies a pluralistic approach, analysing relations between topics and developments, at four interconnected levels of social analysis to explain both positive and negative relations between institutional topics and developments. This has been added in the last two rows of Table 1 and is discussed in the next sections.

5.2. Big data economics and the data economy

In Section 2 we argued that many innovation pathways that try to tackle the grand challenges are linked to the developments in ICT, being the latest industrial revolution (Perez, 2002). This leads to new technologies that make new observations on the ecological system, animals and human health possible and lead to much more data for decision-making. It also helps to better understand ecological processes like in soils and correct some of the rude interventions

Table 1. A multilevel analysis of multidisciplinary collaboration and the role of agricultural economists

	Level 1	Level 2	Level 3	Level 4
Level of analysis	Social embeddedness	Institutional environment	Governance structure	Resource allocation and employment
Description	Informal rules of the game (common understanding) and taking a long time to change	Institutional environment (formal rules of the game)	Play of the game (aligning governance structures with the transactions)	Incentives (and disincentives) for the individuals
General issues in economic research	Culture, traditions, taboos, customs and norms	Laws, regulations, rules and administrative burden	Rule setting, implications of rules (incentives), enforcement of rules and roles and responsibilities	Prices, quantities, profits and costs and benefits
Research focus	Social aspects	Property rights	Governance model and contractual relations	Prices and quantities
Speed of change according to Williamson (2000)	100–1,000 years	10–100 years	1–10 years	Continuous
Issues in multidisciplinary research	Differences in language (implicit assumptions, terminology and jargons), world views and belief systems	Intellectual properties, journals and academic institutions	Collaboration agreements, working methods and grant requirements	Time and budget requirements
Factors increasing transaction costs and/or risk of achieving research goals	Lacking common language and methodology and lacking shared project vision and approach	Bureaucracy in management and funding	'Disciplinary chauvinism'	'Perceived parasitism'

(continued)

Table 1. (Continued)

	Level 1	Level 2	Level 3	Level 4
Level of analysis	Social embeddedness	Institutional environment	Governance structure	Resource allocation and employment
New research topics	Trade-offs between different value and belief systems	Intellectual property rights, privacy laws, data ownership, farm data autonomy, data sovereignty, IT infrastructure and network effects	Soft law (certification schemes and labelling), contracting, platform economics, data economy, decentralised governance systems, etc.	Big data statistics, big data econometrics, AgTech funding and investment, etc.
What agricultural economists can do to move to food economists?	Considering/translating different world views in scenario developments, design desirable futures, development of multidisciplinary ontologies, reference models and data models	Organising managerial support, 'institutional entrepreneurship', economics of networked organisation forms and design policy interventions that transform the systems	Assessing transaction costs and effectiveness of new governance models; opportunities and impact of data economy, new business models and collaboration forms	Making use of big data, new monitoring methods, more attention to the role of the food environment (consumer level) and local environmental farm production circumstances

with chemicals and heavy machinery of the last 75 years. Data and knowledge will substitute such inputs: the future of agriculture is in ecology and data, less in chemicals and heavy machinery. Data and knowledge will also help to better quantify trade-offs. The advancement in ICT and the explosive growth of digital data in agriculture and beyond leads to big data economics (Coble *et al.*, 2018).

This trend has a number of consequences. Economists could make much more use of new big data sets and adjust their models accordingly (Einav and Levin, 2014; Storm, Baylis and Heckelei, 2020; Zilberman, 2019). Precision farming will lead to a deluge of data and it will become easier to collect for instance sustainability data in well-known data sources like the farm accountancy data network (FADN) (Poppe and Vrolijk, 2018) and to model trade-offs between different aspects of sustainability and income. Economists should use and improve their valuation methods to calculate true costs of activities and products (Jongeneel, 2020). This also helps to design, monitor and evaluate agricultural and environmental policies as announced in the European Commission proposal for a Green Deal and the Farm-to-Fork Communication.

Sustainability problems in food systems do not only show up with farmers and the effect of farming on the climate, environment, animal welfare, public health and labour conditions. Also at the consumer side of the chain public health issues, food waste and (non-)demand for sustainable products are problematic. Here ICT could also play a role in supporting citizens in more healthy and sustainable food consumption and lifestyle. The assessment of government interventions, be it labelling or taxes or regulations on the food environment, would benefit from an equivalent of the FADN. Interesting proposals to develop such a citizen data platform in a transdisciplinary approach have been developed (Poppe *et al.*, 2018a; Snoek *et al.*, 2018), in which consumers could manage and share their data with research from retail loyalty cards and apps. As the health sector is paying much more attention to preventive health in addition to curative medicine, and new ICT-based technologies (genomics on the biome and neurosciences) will enable us to learn more on the relation—food and health, this could be embedded in a food, nutrition and health research infrastructure.

With improved data sets at farm and consumer levels, a better understanding of behaviour under conditions of changes in government policy or technology will be possible. Trade-offs and how they are or could be handled become more clear. This type of activities by agricultural economists typically fit into the fourth level on the NIE framework: studying the outcomes of the resource allocation under different conditions.

Big data economics implies that there is also work to do on the institutional environment and the governance structure for the platform economy that characterises the ICT revolution. More attention can be paid to the exchange of data, either coupled with products and services or on its own. European projects like IoF2020 (www.iof2020.eu) and Smart AgriHubs (https://smartagrihubs.eu/) learn that introducing ICT in food chains is as much a social challenge that asks for the design of business models and data governance mechanisms, as it is a technical challenge (Wolfert *et al.*, 2017). Farmers, supply and food companies (including cooperatives) and ICT start-ups have to find new ways to farm and combine data. This leads to data platforms that can change the power dynamics as network effects in data can lead to monopolies.

5.3. Design of institutions and governance of the food system

The rise of big data economics not only provides agricultural economists with big data and big data analytics that may fundamentally change the way economists derive quantitative inputs and insights (Einav and Levin, 2014), but the development will also have an effect on transaction costs, and hence on institutional design and arrangements. The impact of big data and ICT on markets and institutions has already been noted as the 'platform revolution' (Parker, Van Alstyne and Choudary, 2016). There is clear evidence in tourism (with AirBnB having an effect on the hotel market but also the housing market) and in food (Uber Eats and other delivery services). Not only robots and driverless tractors are coming, but the milking robot is now starting to replace dairy factories for milk, providing consumers with traceability to the individual cow.

Economists are well-known for their supply and demand curves and perfect competition as a reference model, but most of our food chains do not very well resemble that text book ideal (Boehlje, 1999; Poppe *et al.*, 2015, 2013). The frequently used 'ceteris paribus' condition almost never holds in food system dynamics. Organisational arrangements affect behaviour of the players, but this goes often unnoticed. New technologies can have an effect on how food chains are organised for instance giving retailers, food processors and their sustainability schemes more control over farmers or creating decentralised governance systems via distributed ledger technology (popularly known as the blockchain technology). More attention to institutional aspects to understand how these chains are organised and how that will change under new technologies or can be changed to improve the sustainability performance of food systems would be welcome. NIE gives agricultural economists a toolbox to help redesign food systems, making them more sustainable and resilient in the new data economy.

Food economists should not only investigate current (new) institutional and governance arrangement but in a multidisciplinary approach they should also pay more attention to designing such food systems relative to understanding how they work. That would bring more common ground between natural scientists and food system economists and reduce current tensions where economists sometimes find themselves at the end of the project reducing high expectations of an engineering dream.

At the level of social embeddedness food system economists should focus more on the tension between the technological developments and the cultural views on the rural area and food production. Agriculture is industrialising, often at the expense of nature and biodiversity and with much less employment in the rural regions. There is a need to translate different world views and cultural values in scenario developments and the design of desirable futures.

This creates a need for long-term models that investigate options for climate policy, look into the environmental claims of precision farming and take demographic trends into account in a dynamic way. Policymakers and planners are interested in the trends in the rural areas during the next 30 years and more, and it would be nice if food system economists could deliver.

6. Conclusions

The philosopher of science Karl Popper (1963) wrote: ‘We are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline.’ With the current climate and other sustainability issues related to our food and rural areas, the problems are challenging. These grand challenges should make agricultural economists think how they maintain their relevance. That this is not taken for granted is shown by the original Intergovernmental Panel on Climate Change panel that investigates how the world should deal with climate change: its composition did not include any economists. Economists do not play such a big role in policy as in the 1950s and 1960s (Appelbaum, 2019).

The counterfactual we formulated is a world without agricultural economists. In such a world some of the standard techniques of agricultural economics will survive and used by less-experienced social and natural scientists. Given the grand challenges and innovation pathways that is an unattractive idea. As a quasi-discipline agricultural economics should be reoriented to the grand challenges that require a food systems approach and consolidate its institutional strengths. Where the focus of agricultural economists has shifted from land and the farm to the food chain, consumer and environment, the next step (on the X-axis in Figure 1) should be connecting the dots across the food system itself.

Such a systemic approach to the analysis of food systems asks for a better collaboration with other (quasi-)disciplines and stakeholder engagement. However a multidisciplinary approach does not come automatically. Barriers between (quasi-)disciplines exist. In AKIS, steps have been taken to foster collaboration, but more is needed. As suggested by a recent Nature Magazine editorial that is calling economists and scientists to reunite, other disciplines are open for such collaboration (Editorial, 2020).

The revolutionary development of ICT that helps to replace undesired inputs with knowledge and big data offers an innovation pathway that food system economists should investigate and help to design. NIE is an attractive framework and shows that agricultural economics could help to design a better food system by not only looking to market outcomes in terms of income or environmental or social performance. Problems at that level can be corrected or prevented at a higher level: that of market organisation, law or culture. Food system economists should not only analyse but also design food systems at those levels.

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